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Using a radio controlled model, this study investigated a new type of wing-in-ground effect seaplane.

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Report MDC J7466

FLIGHT TEST OF HYBRID SEAPLANE MODEL

CONTRACT No. N00600-76-C-1602

DAVID TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

10 FEBRUARY 1977

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FLIGHT TEST OF HYBRID SEAPLANE MODEL

Introduction

A new type of wing-in-ground-effect seaplane has been under limited study by NASA, the Air Force and within the Navy. For instance, one of the many concepts currently under evaluation in the Navy's "Advanced Naval Vehicle Concepts Evaluation" (ANVCE) program is this new concept.

The vehicle concept features a low aspect ratio end-plated wing with plain flaps deflected for takeoff and landing. Forward mounted engines deflect their exhaust air beneath the wings during takeoff and landing providing positive pressure in the under-wing cavity. The vehicle is thus lifted partially out of the water, greatly reducing the level of the conventional seaplane hump drag. Significantly less installed thrust compared to a conventional seaplane is possible and greater sea state takeoff capability can result. Since much of the forward engine thrust is dissipated by the interaction with the wing, separate engines to provide additional acceleration thrust are mounted on the aft fuselage or vertical tail.

The vehicles generally have a lower lift-to-drag ratio than high performance conventional aircraft because of the low aspect ratio wing. They have, however, a superior structural efficiency which results from the low aspect ratio wings, higher design wing loading (less wing area for a given gross weight) and less installed thrust.

One of the outstanding uncertainty areas of these vehicles is a thorough understanding of the takeoff and landing operations. This report summarizes an attempt to gain insight into this area through the use of a low cost free flight radio controlled model. The work was conducted under contract N00600-76-C-1602 to the David Taylor Naval Ship Research and Development Center.

Program Objective:

The objective of this program was to study alternative water takeoff and landing procedures for these vehicles and to develop a better understanding of their characteristics during these modes of operations. Identification of potential technology needs and programs necessary to increase the confidence level in the viability of the concept was also anticipated.

Planned Program

The objectives of the program were not attained primarily because of the use of an inadequate low cost stability augmentation system (SAS). A description is therefore given of the intended content of the model program.

Wing-in-ground effect vehicles of the type under consideration are known to be longitudinally unstable. The primary potential problem area to be addressed prior to initiation of successful takeoff and landing tests, therefore, was longitudinal flight stability. That is, it was judged to be expedient to decouple and solve the basic stability and control problem of the vehicle independent of and prior to approaching the complex takeoff and landing problems. The model tests were restricted to the longitudinal degrees of freedom by tethering the vehicle to a center post and operating it in a circle of about 100 feet diameter. The vehicle was thus free in pitch and heave and was fully responsive to thrust and drag forces. No lateral or directional control provisions were therefore made on the model for these tests.

The program was thus divided into two consecutive phases;

- Phase I. Flight of vehicle over a land surface to develop an adequately stabilized configuration.
- Phase II. Flight of the vehicle over a water surface to study the takeoff and landing characteristics.

Phase I was initiated on the Douglas premises at Long Beach with removable wheels on the vehicle. Phase II was scheduled to be accomplished on a reservoir of the Irvine Company approximately 30 miles from Long Beach.

The SAS system was found to be inadequate for vehicle stabilization during the Phase I tests and the Phase II hydrodynamic tests have therefore not been attempted. The program has been terminated as infeasible within the scope of the contract funds.

Model Description

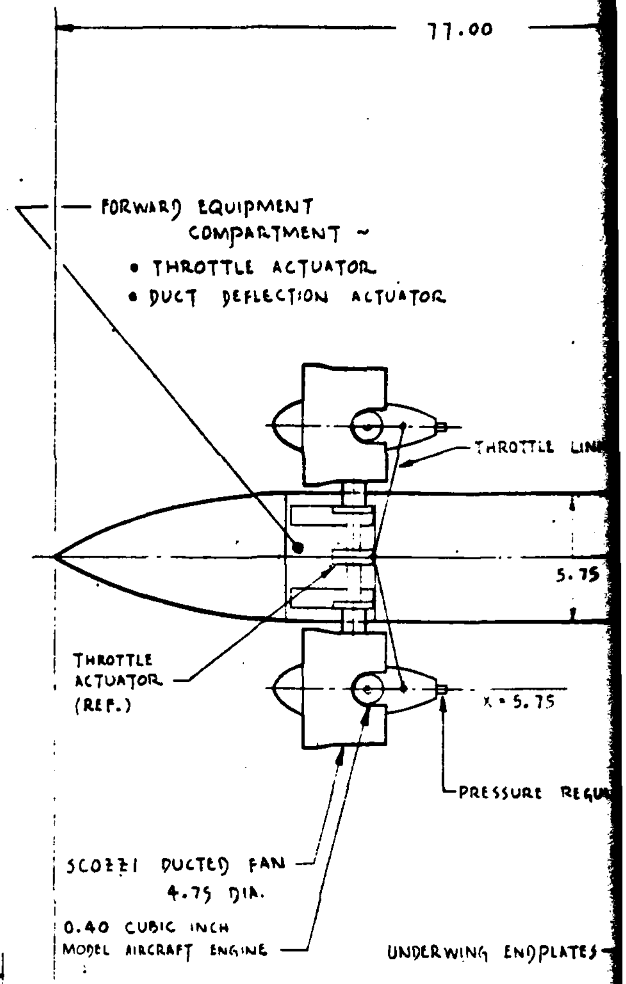
The model built for the test program was designed and fabricated without drawings and generally used model airplane construction techniques. This approach was made possible by using personnel with extensive personal radio control model airplane experience. The basic structural material was bass plywood, foam and epoxy. A three view drawing of the vehicle is shown in Figure 1 which includes basic vehicle dimensional data and model equipment used.

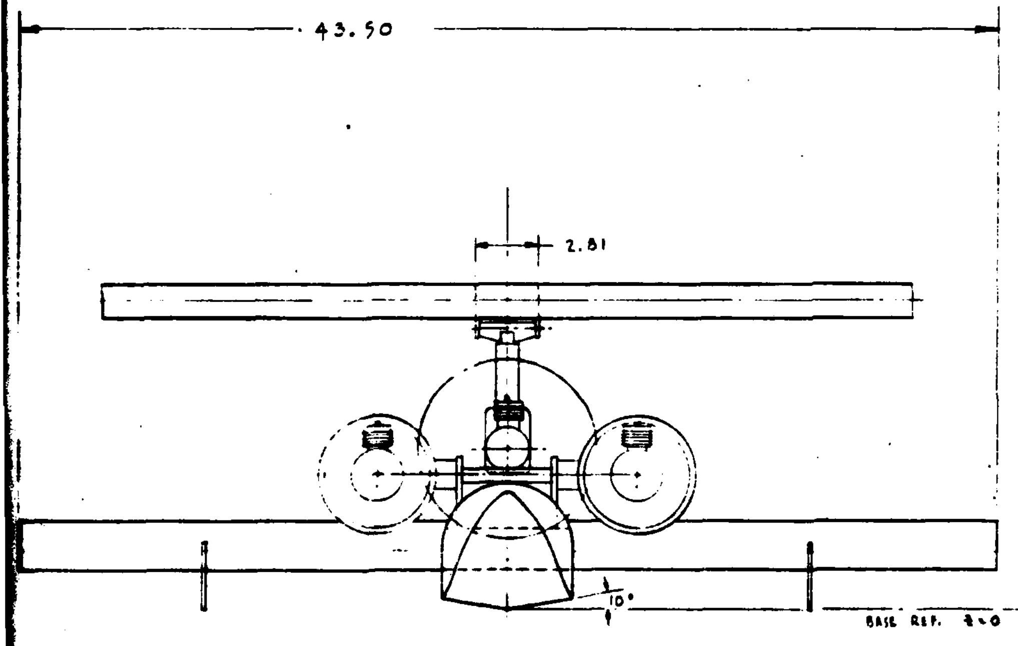
The wing can be positioned fore and aft to facilitate variable center of gravity studies. The vertical height and incidence of the wing can also be varied. A removable hydrodynamic step can also be positioned at three fore and aft locations for test flexibility. Photographs of the model as it now exists are shown as Figures 2, 3 and 4.

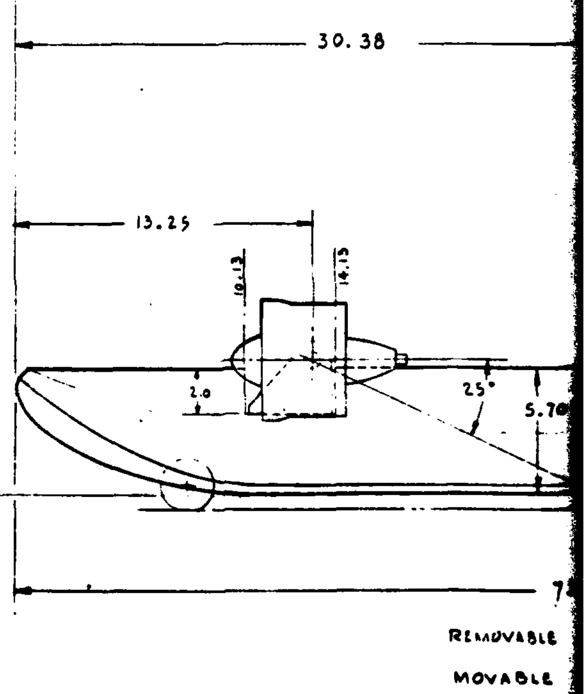
The forward propulsion units consist of two plastic ducted fans built by J. J. Scozzi, Inc. of Washington, D.C. They are driven by conventional .40 cubic inch racing K&B model engines. These units are rated at 6 pounds of thrust each. The fan unit includes a fuel pressure regulator mounted to the aft centerbody. The fans are mounted to a single truss mechanism which allows the units to rotate in pitch so as to achieve power augmented ram (PAR) operation. A single Kraft model servo provides the actuation power. The thrust is modulated through a second single Kraft servo mounted on the vehicle centerline.

A third O.S. Max .20 cubic inch model engine with propeller is mounted midway on the vertical stabilizer. A third servo operates the throttle of this engine.

CHARACTERISTICS DATA			
ITEM	WING	HORIZONTAL TAIL	VERTICAL TAIL
AREA, SQ. FT.	4.268	3.000	0.550
ASPECT RATIO	3.079	3.0	1.164
TAPER RATIO	1.0	1.0	1.0
SWEEP ° C/4	0°	0°	15°
DIHEDRAL	0°	0	~
THICKNESS, %	16.0	12.5	12.0







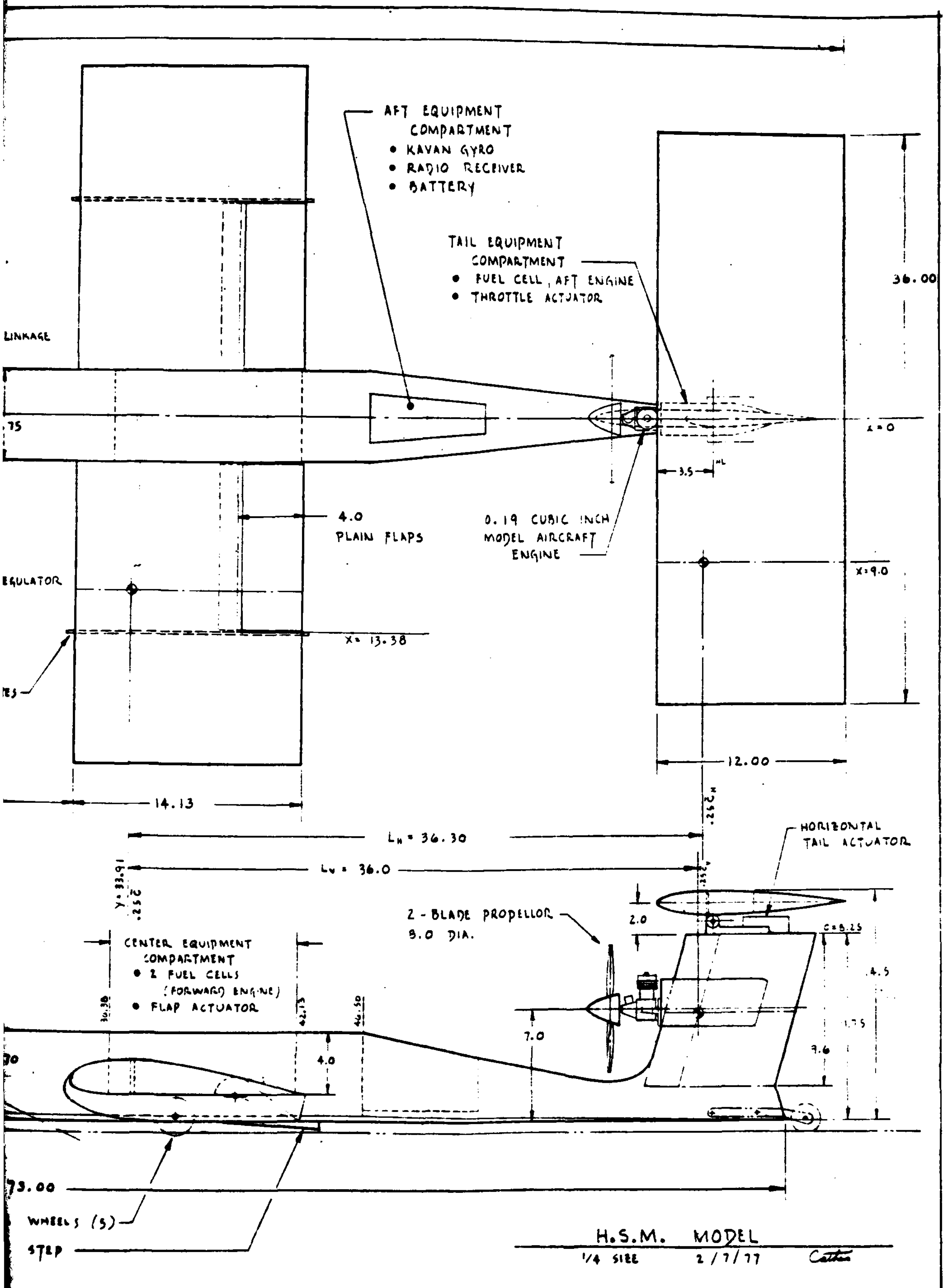


Figure 1. Three-View Drawing of Test Model

Figure 2. Test Model

Figure 3. Test Model

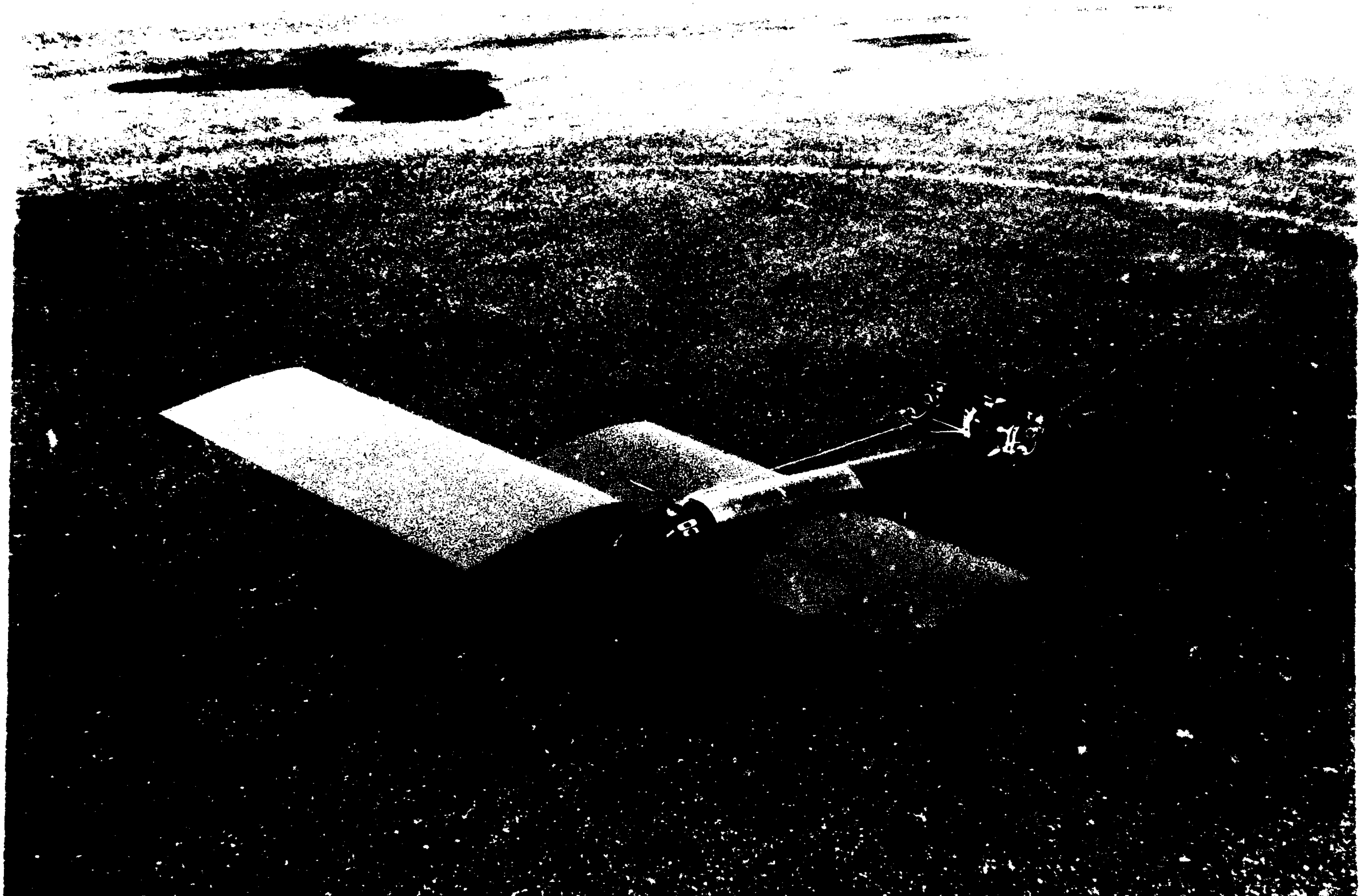


Figure 4. Test Model

The fuel system consists of two tanks mounted in the center hull for each of the two forward engines. The fuel tank for the rear engine is mounted behind the rear engine in the vertical tail.

The wing is 4.3 square feet in gross area and has an aspect ratio 3 rectangular unswept planform. The airfoil is a Clark Y type to preclude suck down pressures as observed on some past ground effect wind tunnel models. An under-wing end plate is mounted 2/3 of the span outboard on each wing panel to provide spanwise sealing for the exhaust air from the forward engines. The aspect ratio of the "PAR portion" of the wing is thus 2. A 25 percent chord plain flap over the PAR portion of the wing is used and is actuated from the center hull cavity by a fourth servo.

The horizontal stabilizer is a one-piece movable surface actuated near the pivot point. The vertical stabilizer is also of one piece with no rudder. A rudder could easily be added for eventual full free flight testing.

The model thus uses 5 channels for proportional actuation for the following functions;

1. flap position
2. stabilizer position
3. forward engine thrust (2 engines)
4. forward engine deflection angle (2 engines)
5. rear engine thrust.

A gyro stabilizing system is installed in a compartment aft of the center hull fuel tanks. This is a small rate gyro built by Kavan and is used by model builders to stabilize model helicopters in yaw (rotor input). The gyro output is input to the horizontal tail servo in series with the manual input through the radio/receiver system.

This same compartment also contains the radio receiver and battery.

For the ground testing phase, a pair of wheels was mounted on the forward hull and one at the rear. Two wheels are also placed at each wing end plate station. The wheels are removable for water testing.

The model is tethered from a wire yoke attached to the hull just fore and aft of the wing. A double strand of wire attaches the yoke to a center post which is anchored into a cement filled tire.

The vehicle weighs approximately 14 pounds and thus has a wing loading of approximately 3 pounds per square foot.

Test Program

The Phase I ground tests were divided into two series involving different vehicle geometry. The original model had a smaller aspect ratio 2 wing and a smaller 15 degree dihedral horizontal stabilizer which included an elevator. After the first series of tests the wing and horizontal tail were modified.

During the first test series a considerable amount of difficulty was experienced with the model equipment, particularly the model gyro. The gyro tended to hunt and at times chattered. Gyro sensitivity to rate inputs was low due to friction in the gyro electrical output pickup contact. Friction was reduced by lightening the contact pressure as much as possible while still maintaining adequate electrical contact. The gyro return spring was replaced with a lower rate spring. The gyro was, in general, modified to the limit of the sophistication of the unit.

The Scozzi fan/K&B engine combination also caused great difficulty. The Scozzi fans are generally not of good quality. The plastic used is too soft and they were easily damaged by the hand engine starter unit. The sub-assemblies of the unit also could not tolerate the vibration of the engines and modifications were necessary.

The model, however, finally reached operational status and a flight test attempted. The vehicle center of gravity was at approximately 50 percent of the wing chord, flaps down approximately 10 degrees and the forward engines slightly deflected for over the wing blowing (to permit lower flight speeds). After several passes the vehicle pitched up beyond 90 degrees and landing on its back. Structural and some equipment damage was suffered. The vehicle did not respond to pilot initiated nose down elevator inputs or to throttle cut back.

The vehicle was structurally refurbished and damaged equipment repaired. At this time several modifications were made. The wing area was increased 50 percent by adding outboard panels onto the existing wing. The aspect ratio was thus increased from 2 to 3. This action was done to lower the wing loading and flight speeds in order to provide more pilot reaction time. The horizontal and elevator system was also replaced with an all-movable surface and the horizontal tail volume ratio increased approximately 25 percent. This was done to add more stabilizing area and to provide more control power.

The vehicle was then put into flight status. A check of the radio transmitter output revealed deficient range and the unit was sent back to the vendor. It was returned and still found to be deficient in range (about 50 feet). Examination by Douglas engineering personnel showed that the radio antennae was not connected to the radio because of a bad solder joint. It has now been concluded that the non-response of the vehicle during the pitch-up of the first flight was probably caused by a weak radio output (the model pitched on the far side of the circle from the controlling pilot - about 100 feet away).

The vehicle was finally flown a second time on December 8, 1976. The vehicle center of gravity was ballasted between 30 and 35 percent wing chord to make it inherently as stable as possible. The wing flaps were again lowered to approximately 10 degrees and upper surface blowing used. A very smooth portion of runway surface was used. The wind was intermittent at approximately 3 to 5 knots (a marginal test condition but typical of local conditions at this time of year).

The vehicle was taxied at incipient takeoff speed for approximately twenty five transits of the circle. Care was taken to achieve a feel for the vehicle characteristics by lowering the flaps, actuating the stabilizer, etc. and the speed was eased up. On one up-wind transit the vehicle again pitched up to approximately 20 degrees. The vehicle responded to down control and throttle shutoff. However, it hit the front wheels and the horizontal tail broke off. This joint was made the weak structural link for this reason. Minor structural damage was experienced but no equipment was affected.

The vehicle has since been refurbished and stored. No motion picture coverage of the test runs was made.

Conclusions

The primary conclusion from the experience gained with the model is that the SAS scheme selected (gyro system) did not have sufficient sensitivity or authority to stabilize the vehicle. A more sophisticated approach is required involving a better understanding of the vehicle SAS requirements in its various flight modes. This would require a considerable amplification of the program to accomplish.

The pitch divergence (and other general flight characteristics) of these types of vehicles is a genuine concern and will require sophisticated avionics black box design. These requirements, however, are probably not beyond the current state-of-the-art once an in-depth understanding of the basic aerodynamic/hydrodynamic characteristics of the vehicles are obtained.

Recommendations

A complete understanding of the basic aerodynamic/hydrodynamic characteristics of these vehicles is not now available and will require an extensive and costly test program to acquire. Much worthwhile insight into the vehicle operating characteristics can still be gained, however, by fulfilling the original objectives and intent of this program. In order to develop an adequate SAS at a reasonable cost, the following SAS program approach is recommended.

1. With the available data base for the aerodynamic characteristics of these types of vehicles (these have been estimated), develop the control laws that will stabilize the vehicle.
2. Set up a simulation of the vehicle and evaluate the system design on the Douglas DETAC non-linear facility.

3. Determine size and output of sensors required and search and acquire existing components where possible.
4. Design servo amplifiers and select servo to drive horizontal surface.
5. Build, assemble and test system. System should be built with maximum degree of flexibility with readily changeable parameters.

The developed SAS would then be installed and checked out in the existing model. The vehicle would be tether flown using the existing radio control system in the Douglas low speed wind tunnel. The tether would restrict the model to some nominal height of the model above the ground board. A thrust tether would also be necessary. The vehicle would be flown in its various operational modes and the SAS tuned as required. The original program as envisioned in this program could then be pursued. It should be pointed out that knowledge gained from the SAS design and wind tunnel program outlined above would be sufficient to justify the program, even if the follow-on flight testing was not conducted.